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AUTHORITY

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STUDY OF ELECTRONIC PACKAGING

STANDARDIZATION CONCEPTS

For

Department of the Navy
Naval Electronic Systems Command
Washington, D.C. 20360

Contract No. N00039-69-C-0539

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SUMMARY

This report contains the results of a study of alternative approaches to standardized packaging of Navy electronic systems. Existing Navy standards are described and principal advantages and disadvantages of each type discussed. Comments of industry personnel concerning present standards in NAVMAT P3940, Navy Systems Design Guidelines Manual, Electronic Packaging, are presented together with potential procedures for implementing further standardization. Preliminary information is given for several industrial packaging systems under development by contractors. Examples of life cycle cost considerations are given for two typical systems, one a mechanical standard and the other a functional standard. These examples illustrate the difficulty in estimating the dollar costs for a particular type of standardization. Evaluation criteria are presented to assist a project manager/engineer in determining the applicability of the NAVMAT P3940 standards to a specific system or program. Guidance for the implementation of standards in a given system or program including contractural provisions are included. The last section contains recommendations and conclusions, which are summarized in the following paragraphs.

The application of appropriate packaging standards presents a large potential saving for the Navy. Although it is not possible to calculate precise dollar savings over the life cycle of equipment, an estimate of the impact on equipment costs can be made. Each application must be considered individually and the evaluation should be done by project personnel, assisted by electronic packaging specialists. Standards will be widely applied in Navy programs only if there is a strong effort to insure that they are specified in procurement documentation. It would help if special funding is provided to cover the extra initial costs of standards. This funding should be outside individual project budgets.

A packaging standardization group should be established in CNM to coordinate and assist projects and programs. This organization should spearhead the effort to maintain and update standards, explore possible adoption of new standards (especially the avionics equipment) and prepare suitable procurement documentation for the projects.

I. CONDUCT OF STUDY

This is the final report of the work performed by Booz, Allen Applied Research, Inc. (BAARINC), under Tasks 1 through 4 of Contract N00039-69-C-0539 for the Department of the Navy, Naval Electronics Systems Command. The subject of the contract is the Study for Standardization of Electronic Packaging Concepts. The project's Technical Officer is Mr. John Merz (OOT-23). Work covered in this report was performed between January 17, 1969 and September 30, 1969.

1. OBJECTIVES OF STUDY

The primary objectives of this effort were:

- Development of effectiveness analyses of existing standardized electronic packaging systems, based on technical and cost factors, and identification of the potential benefits of each system.
- Survey of users and developers of packaging systems to discuss workable procedures for the description and use of new standards which could be included in a Navy manual of standard electronic packaging.
- Analysis of comments on the designs of the packaging benchmarks presented in NAVMAT P3940.
- Development of plans and procedures to increase the understanding and effective use of standard packaging systems.
- Development of guidelines for including requirements for standardization in Government contracts.
- Organization of presentations for Navy personnel to publicize standard packaging programs.

2. AREAS OF STANDARDIZATION COVERED

This report deals with electronic packaging at the module level and higher. Discussions of component packaging methods such as mounting and interconnecting circuit components of an individual integrated circuit are not included. Aspects of packaging Navy electronic systems at the module and enclosures levels of assembly are covered for shipboard, shorebased, and airborne installations.

II. STANDARDIZATION CONCEPT

Packaging standardization as used in this study refers to the use of the same elements, parts, or methods in the fabrication of functionally independent systems. The purposes of the packaging systems include the physical support of electronic circuits, protection from operating environment, thermal control, signal and power distribution, interconnection of mechanically separable units, and support for displays and controls.

The present status of most electronic systems is such that many of the devices and components used in airborne, ship, and shore installations require different enclosures, different connectors, different maintenance, and different fault indicators and isolators. In order to reduce this complexity, and to improve reliability, maintainability, and availability, standardization of suitable equipment should be accomplished. Although procurement costs may be higher, life cycle costs will be reduced.

It is important that flexibility be considered throughout the development of standardization requirements. Because of design and other limitations, some packaging cannot at present be practically or beneficially standardized. For this reason, it is important that a careful evaluation be conducted for each system under consideration.

1. APPROACHES TO STANDARDIZATION

Selection of the type of standardization for a particular system requires a thorough analysis of system functions and proper evaluation of the designs within the applicable system effectiveness requirements. Each of these approaches allows the designer a wide latitude of variation in physical dimensions and fabrication techniques while maintaining commonality of mechanical interfaces.

Packaging standardization may be classed as functional, mechanical, or methodological. Functional standardization refers to the electronic circuit function contained by a separable package element (module). These functional elements form the building blocks of electronic systems and have both electrical and mechanical interfaces.

Mechanical standardization refers to the definition of all packaging system elements and interfaces other than electronic functional elements. Methodological standardization refers to the specification of preferred techniques for implementing some function of the overall packaging system or of the electronic function of the system. All classes of standardization could have separate standards for each type of installation and equipment class, or combinations or some single standard could be applied across all installations and equipment classes.

Performance and cost factors of each standardization approach are detailed in Chapter III of this report.

2. EXISTING STANDARDIZED SYSTEMS

Military electronic equipment contractors usually apply some type of standardization in building functionally different systems. The type and amount of standardization depends on the type of system and its installation environment. Mechanical and methodological standardization are much more common in industry than functional standardization.

(1) Navy Standards

Reference 1, NAVMAT P3940, Navy Systems Design Guidelines Manual, Electronic Packaging, contains information concerning those packaging systems which are considered "benchmarks" of packaging approaches. Each system is described briefly in the following paragraphs:

- Standard Hardware Program (SHP). The SHP modules are an example of functional standardization. These modules are a family of functionally, dimensionally, and mechanically specified plug-in replaceable modules intended for broad application to various electronic systems in ship and shore installations. The concept was developed by the Naval Avionics Facility, Indianapolis (NAFI).

- Electronic Packaging System (EPS). The EPS modules and enclosures form a total integrated packaging system, and provide an example of mechanical standardization. The EPS is designed

for broad application to surface shipboard installations. The Naval Electronics Laboratory Center (NELC), San Diego, is the originator of this benchmark system.

- Central Computer Complex (CCC). The CCC modules are an integrated packaging system designed specifically for a digital avionics system. The design is intended for an airborne installation and was developed by the Naval Air Development Center (NADC), Johnsville.

- Centralized Electronic Control (CEC). The CEC modules and enclosures form a total packaging system designed for broad application to shipboard and submarine installations. This concept was developed by the Naval Research Laboratory (NRL), Washington.

(2) Industry Standards

Reductions in overall costs and simplification of logistic support have induced industry to introduce standards of uniformity into present electronic and microelectronic packaging. Several companies were contacted concerning their experience with standardization. For reasons varying from "different customer requirements" to "rapidly changing technology", most of these companies did not maintain a complete standard packaging system at the module level or above. Some maintained the documentation and tooling necessary to procure enclosure shells for shipboard use from metal products companies or on an as-needed basis. The type of chassis and cabling arrangement selected was determined by the particular design system. The following paragraphs describe some of these in-house efforts in developing standard modules and enclosures.

- Martin-Marietta Corporation, Orlando Division, has developed a family of digital printed circuit cards which are approximately 4 x 5 inches, with 60 to 80 pin connectors. The technique is a high density design capable of accommodating up to 30 flat pac IC's (integrated circuits) per board. For proprietary reasons, the company could be reluctant to release the design for consideration as a Navy standard.

- **Raytheon Company**, Submarine Signal Division, is developing an enclosure system for submarine use capable of accommodating SHP modules. The preliminary design features will include:

  - Enclosure dimensions - 70 inches high (width and depth to fit 25-inch hatch)
  - Two vertical pull-out slide-mounted serviceable chassis per enclosure
  - Each chassis contains a fixed and a hinged frame
  - Each frame holds a page of single span, single thickness SHP modules with 44 inches of vertical usable rack space
  - An integral thermal control unit utilizing the ship's fresh water as the heat removal medium for each enclosure mounted in the bottom.
  - Designed to meet all MIL-E-16400 specifications.

  Design completion is scheduled for December 1969. Raytheon would consider disclosing the design for use as a Navy standard.

- **General Electric**, Heavy Military Electronics Division, has a design for a complete standardized packaging system. The main features include:

  - Designed for shipboard use
  - Similar to NEL enclosure system
  - Printed circuit card dimensions are 4.7 x 4.7 inches with 56 pins. 0.1 inch centers. Connectors are similar to those of SHP modules. Spacing between cards is 0.4 inch.

At the time of the interview, it was undetermined whether GE would disclose the complete design for consideration as a Navy standard.

- General Kinetics, Inc., Allo Metal Products Division, is planning to produce an enclosure system with the following features:

  - Enclosure dimensions of 24 x 24 x 72 inches
  - Designed for surface shipboard installation and to meet all MIL-E-16400 specifications
  - Design of serviceable chassis similar to NELC enclosure system, with two vertical slide-mounted chassis per enclosure
  - Each chassis contains a fixed and hinged frame, with each frame containing a page of modules
  - No thermal control units other than a filtered blower
  - Approximate weight 500 pounds
  - Mounting is rigid to ship deck.

III. PERFORMANCE AND COST FACTORS

In each case the final decision as to where and how to apply standardized packaging concepts will probably be based on cost and performance factors. A comprehensive cost model which would clearly establish at least part of this information would be desirable; however, the necessary data are not presently available in the quality and quantity necessary to develop such a model.

Performance and cost factors have been evaluated for the functional and mechanical approaches to standardization, and for the phases of R&D, production, and operation within each approach. An effectiveness assessment is also presented in this chapter, along with comments from those who have experienced to some extent the development of various types of standardization in electronic packaging. An example is supplied for each of the two major approaches.

Appendix A contains detail comments on the technical characteristics of the concepts considered.

1. MECHANICAL STANDARDIZATION APPLICATIONS

Mechanical standardization is generally applicable at the system level, although portions of the packaging system can be standardized for use with all procurements, equipment and installations, and/or electronic systems. For instance, a module size or form factor may be standardized, or the design of the racks or enclosures. There are advantages to this partial approach regardless of the assembly level at which it is applied. Maximum benefits are provided by a complete packaging system, such as the CEC or EPS, described below. Full implementation of the module approach can be achieved by keeping the number of designs low and proprietary interests minimized.

(1) Performance Factors

- R&D Phase

  - Reduced Development Costs. This is realized from a reduction in the engineering cost for

the packaging system, reduction of performance verification testing, and a reduction of the documentation required.

Naturally, the amount of cost savings depends on the applicability of the standard to the electronic system requirements. The need for extensive modification of the standard will negate or reduce this advantage and others.

- Increased System Reliability. Reliability is perhaps the greatest advantage of mechanical standardization. This is achieved by concentration of development effort on relatively few packaging system components and extended environmental testing. Use of a standard packaging system would permit a more direct application of field-gathered reliability data to future systems. The standard, however, must be flexible enough to allow the continuing development as directed by field data and changes in the state of the art.

- Reduced Development Time. Lead time is shortened since the standard will be readily available from qualified sources with adequate documentation.

- Volume and Weight Penalties. These penalties may occur to adversely affect system effectiveness since a standard packaging system must be suboptimally designed for broad use in functionally independent systems. Use of a standard may require a larger volume or greater weight than a special purpose design.

  The degree of this disadvantage depends on the electronic system function and installation.

- Contractor Reluctance. This natural inertia-like resistance can be attributed to such factors as personnel preference, use of contractor's own packaging system design, and lack of familiarity with the standard packaging system.

- System Partitioning Accommodation Cost. Use of a standard packaging system could require changes in a contractor's way of system partitioning to accommodate the standard. This could tend to increase the system cost or reduce competition.

- Overdesign of Standard Packaging System. Standard packaging system capabilities may exceed the particular system's design requirements. This will increase the cost of the packaging system hardware. The overdesign cost penalties may be minimized by second-source supply, high volume use, and a reduction in documentation.

- Performance Liability. When the government specifies a standard for use in the system design, this tends to complicate the situation regarding liability should nonperformance of the packaging system occur.

- Static Nature of a Standard. In general, once a standard is established, it is difficult to change as the state of the art changes. A periodic updating of a standard can minimize this disadvantage.

- Cost of Standardization Program. Cost of maintaining, updating, and implementing mechanical standardization program should be considered.

- Production Phase

  - Reduced Cost of Production System. The overall cost of production quantities of the electronic system would be reduced by having multiple sources of supply of the packaging system and a higher level of quality control through high volume use.

  - Reduced Time to Volume Production. Standard is readily available through high volume use.

- Reduced Shipyard Installation Costs. More standardized instructions would be possible, thus reducing time and cost to install electronic systems.

- Design Penalties. The overdesign penalties covered in the R&D phase may occur in this phase as well as the performance liability question.

- Operation Phase

  - Reduced Maintenance Costs. The number of different packaging system parts between functionally independent systems is reduced and this reduces the training required of servicing technicians. Increased packaging system reliability reduces corrective maintenance required.

    The degree of increase depends on the number of systems using the same standard packaging system and how many are on the same platform.

  - Reduced Support Costs. The number of different spare parts is reduced as well as supporting documentation. Also, the standard will afford the government a better chance of competitive procurement of nonproprietary spare parts.

    The degree of reduction in support costs depends heavily on the reliability of the packaging system components and on how many standard packaging systems are used.

(2) Effectiveness Assessment

Interviews were conducted with representatives from various companies to obtain a sampling of opinion concerning the effectiveness of present standardization packaging techniques. It was apparent from these discussions that many in industry had reservations about Navy standardization concepts and prospects for standardization requirements.

While the various approaches to standardization do offer a wide latitude in system design, some industrial representatives seem unconvinced that the competitive and innovative environment within industry will be maintained. The following paragraphs present the industry comments, along with an evaluation of some of the factors involved.

Most of those interviewed expressed these general views of the EPS enclosure system:

- Overdesigned for general shipboard use.
- No necessity for the apparently expensive and bulky pressure-cam type of printed circuit board connector.
- Overall construction is good but expensive.
- Interchassis wiring arrangement occupies too much space (wiring between vertical chassis).
- Long vertical pull-out chassis may be subject to excessive side-to-side vibration.
- Moisture seal (between pull-out chassis door and enclosure shell) appears weak.
- Tight tolerance required on chassis door latch assembly increases cost.
- Use of SHP modules in EPS enclosure system reduce volumetric efficiency.

It is not obvious that the EPS enclosure system is overdesigned for general use in surface ship installations. Its maintenance features provide accessibility and safety to maintenance personnel which are in line with good sound practice for almost any attended shipboard electronic system. The systems ability to meet the environmental and other requirements of MIL-E-16400 provides a high degree of confidence in its reliability. The design also incorporates a high degree of versatility. A summary of the test results should be made available and perhaps be included in the next revision of NAVMAT P3940.

The family of various racks (see References 1 and 2) and enclosure heights should provide enough of a variety to allow use of the EPS enclosures on most surface ship electronic systems.

As mentioned earlier, the feature of EPS most often critiqued is the printed circuit board connector, which operates on a pressure-cam principle. This connector was chosen because it provides an increased contact density and contact pressure for added reliability without the usual increase in insertion and withdrawal forces (Reference 2). Further tests and evaluations should be conducted before this type of connector is considered as a standard. Reference 3 provides the results of one series of tests conducted on this connector.

The vertical serviceable chassis is designed to be compatible with other types of planar printed circuit board connectors and module sizes. The usable widths of the three types of vertical serviceable chassis (7.6, 3.8, and approximately 17 inches) and the capability to vary the length and thickness provide enough design flexibility to accommodate several module sizes without a great decrease in volumetric efficiency.

Reference 4 contains data gathered from over 30 material and component suppliers, system manufacturers, and users of electronic equipment. For the future (through 1975 for large production equipment), there seemed to be no particular interest in determining standard sizes, since sizes were considered a function of specific packaging requirements.

Reference 5, which is the report of the initial study resulting in the EPS concept, contains some interesting conclusions and insight into the reasoning behind this concept. While recognizing the strong and rapid trend toward extreme reliability, density, redundancy, and automatic maintenance (negating the need for ready accessibility), it was felt by some that maintenance will be necessary at the modular component level for many years to come. This feeling resulted in heavier weighting on accessibility than the majority opinion would have indicated. It was forecast that equipments of the future would be almost entirely modularized, with on-line maintenance being essentially a plug-in operation, except for fault isolation. (Reference 5, Section II). Several reports and systems studied also showed that most equipment can be designed or adapted to some minimum size standard enclosure.

Although these conclusions were reached in 1964, they appear even more applicable at the present time with the increasing use of microelectronics. Except for systems requiring large operator consoles and displays built as an integral part of the equipment enclosure industry representatives agree that the EPS is applicable to most surface ship installations. However, some analysis is required for each application to determine relative importance of system requirements.

The EPS submarine enclosure is the same as the surface ship design except it can be disassembled to allow passage through a minimum amount of disassembly for installation. This is usually no lower than the enclosure level (6 x 2 x 2 feet) for normal shipboard installations. For this reason, it seems impractical to use the present EPS enclosure in submarine installation.

Use of the EPS in shore installations does not appear cost effective where several enclosures are to be used. EPS design was based on a shipboard environment; normal Naval shore installations would not require the mechanical rigidity nor necessarily the type of heat exchanges.

It has been recommended that more information about the EPS design concept formulation process be included in later revisions of NAVMAT P3940 in order to aid in determining its applicability for a particular system. Also, the several documents which NEL provided for BAARINC during this study (including References 5 and 6) and any others generated during the EPS design should be referenced in NAVMAT P3940, as well as appropriate assembly drawings.

The CEC module is similar enough to the EPS to make their mutual inclusion in NAVMAT P3940 seem unnecessary. Also, as a mechanical packaging standard contained in NAVMAT P3940, it should have complete procurement specifications available.

There were few comments concerning the CEC concept:

- Enclosure might not pass environmental requirements of MIL-E-16400.

- Any enclosure system should contain provisions for neat exchangers on a single enclosure basis, not depending on a group of enclosures being placed side-by-side.

(3) Cost Estimates

Standardized designs may appear initially more costly than nonstandardized designs, especially in the R&D phase which includes procurement of a prototype. However, when the life cycle costs are considered, as well as the savings in redesign and maintenance effort and training over the years, a strong case may be developed for standardization.

The following example of an application of mechanical standardization will assist in identifying the cost factors to be considered in this approach to standardization.

The AN/SPS-XX radar will undergo a major modification. The front end of this equipment, which is now essentially a vacuum tube device will be redesigned to make extensive use of solid state components. Minor changes to the pedestal and the antenna will also be made. The new system will be designated the AN/SPS-XXA. The project engineer must investigate the cost of incorporating the EPS concept where appropriate versus a special or proprietary design for the modified elements.

The following conditions are assumed:

- Twenty-five of the new systems will be produced.
- Expected life of the system is 10 years.
- The redesigned electronics will require four cabinets, each 6 x 2 x 2 feet. EPS is not adaptable to any other elements of the existing system.
- The cost of the electronics and displays will be the same in both cases.
- The cost of modules and module connectors will be the same in both cases.
- Both the EPS and the special design will meet system requirements.
- Another functionally independent system onboard the platform uses the EPS.

- Spare parts for EPS are already in the Federal supply system.
- System manning requirements are one-half technician for shipboard maintenance.
- EPS enclosures are GFE.
- The electronics will be on printed circuit card modules.

The comparison of costs for this example is shown in Exhibit I. Missing estimates are assumed to be due to the project personnel having insufficient input data. However, the absence of these figures does not destroy the usefulness of the method.

Based on the information available to the project analyst, in this example, the incorporation of EPS would result in a net saving of $35,000 over the life cycle of 25 years. Not included in the estimate were spare parts such as connectors and cabling. The cost of introducing 15 new parts into the Federal Stock System was assumed in the special design case.

No cost estimates were made for the value of reliability and maintainability aspects. The reliability of the EPS has been adequately demonstrated, and these factors appear to be on the plus side for this standardized system. The largest cost savings may occur in the area of reduced support costs which cannot be accurately estimated at this time.

It is impossible at this time to assign any value to reduced costs resulting from fewer spare parts on the platform when the number of equipments using EPS are still unknown. It is known that as the quantity increases the saving increases.

The evaluation indicates that the identifiable cost savings of incorporating EPS in this modification of the radar will be modest but probably conservative. No factors have been identified which would appear to weigh heavily in favor of the nonstandardized system. The case for the standardized packaging system is supported by the cost evaluation even though it is incomplete.

LIFE CYCLE COSTS ESTIMATES FOR AN/SQS

STANDARD PACKAGING SYSTEM ELECTRONI

Life Cycle Phase	Cost/Performance Factor	Esti Stan	
		Basic	M
R&D	Engineering Development Costs	250 MH	$1
	Performance Testing (Enclosure Level)	$5,000	
	Enclosure Documentation	100 MH	$1
	System Reliability		
	Development Time		
	Volume and Weight Penalties		
	Contractor Reluctance		
	Partitioning Accommodation Cost	500 MH	$1
	Effects of Reduced Prototype Competition		
	Overdesign of Standard System		
	Performance Liability		
	Static Nature of Standard		
	Maintenance of Standardization Program	$100,000	1/
	TOTAL R&D PHASE NOTES: MH = Man Hours (1) Standardization program costs shared equally by 25 projects.		

H

MATES FOR AN/SQS-XX RADAR
YSTEM ELECTRONIC PACKAGING SYSTEM (EPS)

	Estimated Costs Standard System			Estimated Costs Non-Standard System			Estimated Gain or (Loss) By Using Standard System
	Basic	Multiplier	Total	Basic	Multiplier	Total	
	250 MH	$12/MH	$3,000	2,000 MH	$12/MH	$24,000	$21,000
	$5,000	1	$5,000	$25,000	1	$25,000	$20,000
	100 MH	$10/MH	$1,000	1,500 MH	$10/MH	$15,000	$14,000
	500 MH	$12/MH	$6,000				($6,000)
	$100,000	1/25 (1)	$4,000				($4,000)
cts.							$45,000

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LIFE CYCLE COSTS ESTIMATES FOR AN/SQS-
STANDARD PACKAGING SYSTEM ELECTRONIC

Life Cycle Phase	Cost/Performance Factor	Estim Standa	
		Basic	Mul
PRODUCTION	Enclosure Production Costs	$3,500/ Enclosure (2)	25Sy 4 En
	Time to Volume Production		
	Shipyard Installation Costs Differential		
	Overdesign of Standard Packaging System		
	Performance Liability		
	TOTAL PRODUCTION PHASE		

NOTES:

(2) Cost of enclosure system in lots of 200 or more. The 100 required for systems implementation is GFE.

(3) Based on cost of current CY-4516 cabinet.

A

MATES FOR AN/SQS-XX RADAR
YSTEM ELECTRONIC PACKAGING SYSTEM (EPS)

	Estimated Costs Standard System			Estimated Costs Non-Standard System			Estimated Gain or (Loss) By Using Standard System
	Basic	Multiplier	Total	Basic	Multiplier	Total	
	$3,500/ Enclosure (2)	25 Systems, 4 Encls. Ea.	$350,000	$3,000/ Enclosure (3)	25 Systems, 4 Encls. Ea.	$300,000	($50,000)
				24 MH/ System	$10/MH x 25 Systems	$6,000	$6,000
SE							($44,000)
100							

B

LIFE CYCLE COSTS ESTIMATES FOR AN/S(
STANDARD PACKAGING SYSTEM ELECTRO

Life Cycle Phase	Cost/Performance Factor	Es St
		Basic
OPERATION	Technician Training Costs (4)	$1,900/Yr. (5)
	Effects of Simplified Maintenance Manuals and Procedures	
	Cost of Introducing New Parts in Federal Stock System	
	Cost of Maintaining New Parts in Federal Stock System	
	Effects of Fewer Spares on the Platform	
	Effects of Increased Competition for Spares	
	TOTAL OPERATION PHASE	
	LIFE CYCLE COST DIFFERENTIAL	

NOTES:

(4) Based on a cost of $1,000 to train a technician with a useful life of 2.5 years. System requires 1/2 technician.

(5) Estimated savings of 5% of training costs by use of standard enclosure.

(6) Based on data supplied by NAVELEX.

A

IMATES FOR AN/SQS-XX RADAR
SYSTEM ELECTRONIC PACKAGING SYSTEM (EPS)

	Estimated Costs Standard System			Estimated Costs Non-Standard System			Estimated Gain or (Loss) By Using Standard System
	Basic	Multiplier	Total	Basic	Multiplier	Total	
	$1,900/Yr. (5)	10 Yr. x 25 Systems	$475,000	$2,000/Yr.	10 Yr. x 25 Systems	$500,000	$25,000
				$100/Part	15 Parts (6)	$ 1,500	$ 1,500
				$ 50/Part/Year	15 Parts x 10 Years (6)	$ 7,500	$ 7,500
E							$34,000
L							$35,000
seful							
ndard							

B

2. FUNCTIONAL STANDARDIZATION APPLICATIONS

The SHP module concept is an example of functional standardization. This family of modules is intended to provide building blocks for use in implementing functionally independent systems.

The Standard Hardware Program (SHP) is not restricted to any single system, allows the introduction of new functional modules, limits the use of proprietary designs to areas which do not inhibit competitive procurement, selects and specifies presently used functional modules in such a way that they will not become obsolete due to technical change.

(1) Performance Factors

- R&D Phase

  - Reduced Development Costs. This occurs by a reduction in the engineering circuit design cost of the functional modules, reduction of performance verification testing at the module level, and a reduction in the documentation required to define and support the overall system.

  - Reduced Development Time. Lead time is reduced since complete functional module and piece-parts are available with adequate documentation. The magnitude of this advantage depends on how many existing modules can be used.

  - Improved System Reliability. This is achieved by concentration of development effort, extended testing, and quicker direct application of field-gathered reliability data to future system developments. It is enhanced by increased applicability of the standard modules in the system.

  - More Realistic Cost Bids for System R&D. By specifying use of standard functional modules in R&D requests for proposals from contractors, the tendency for a contractor to "buy-in" is reduced, since he cannot be assured of winning the production follow-on.

- Reduced Packaging Density. This operational parameter may be adversely affected by standardization since some standard functional modules may have a low packaging density in order to be used in different electronic systems. The extent depends on the system and the type of installation.

- Contractor Reluctance. This disadvantage is due in part to unfamiliarity with the functional capabilities of the standard modules and/or the desire to use a company proprietary design.

- Reduced R&D Contractor Competition. This disadvantage would result from the contractor reluctance discussed above. This may be a transient situation as understanding and acceptance of functional standardization advances.

- System Partitioning Accommodation. Use of standard functional modules could require changes in a contractor's scheme of system partitioning. This could tend to increase system cost or discourage competition.

- Overdesign of Standard Modules. As with mechanical standardization, standard modules capabilities may exceed the particular system's design requirements. This will tend to increase the cost of the system hardware. The overdesign cost penalties may be minimized by second-source supply of standard modules, high volume use, and a reduction in system documentation.

- Performance Liability. As with mechanical standardization, government specification of standard modules complicates the situation regarding liability should nonperformance of contract occur.

- Static Nature of a Standard. In general, once a standard is established it is difficult to change as the state of the art changes. A periodic updating of a standard can minimize this disadvantage.

- Cost of Standardization Program. Costs of maintaining, updating, and implementing functional standards should be considered.

- Production Phase

  - Reduced Cost of Test Equipment. The test equipment required to support the system can be used on other functionally independent systems that use common standard modules. This reduces the need for unique test equipment for each separate system.

  - Reduced Cost of Production Systems. This occurs through multiple sources of standard modules, high volume use, and a higher level of quality control.

  - Reduced Time to Volume Production. Standard modules are readily available through multiple sources and high volume use.

  - Aid in Increasing Production Competition. By use of standard functional modules, documentation resulting from the R&D phase will stimulate competition in the production phase.

  - Overdesign Penalties and Liabilities. The overdesign penalties and the performance liability question covered in the R&D phase may also occur in the production phase.

- Operation Phase

  - Increased Savings. By reducing the number of different functional modules between systems, savings will occur in simplified maintenance manuals, module testing procedures, requirements for technician training, and the reduction in corrective maintenance required by an increase in module reliability. The degree of this increase depends on the number of systems utilizing the same functional modules and/or on the same platform.

- Reduced Support Costs. This is perhaps the greatest advantage of functional standardization. Use of interchangeable modules between systems reduces the number of different spare part and test equipment requirements. The government is also in a better position to procure nonproprietary replacement modules.

(2) Effectiveness Assessment

From industry personnel who had been involved in the use of SHP modules came the following comments:

- Overall mechanical design produces a rugged module, especially the connector.
- Packaging density is too low.
- The size (board area and number of pins) is too small, requiring a greater number of intermodule connections thus reducing system reliability.
- Module cost is too high. Most felt that this was a result of the extensive documentation and testing required in module development.

The SHP incorporates features that permit adding of new functional modules to the present family and reduces to a minimum restrictions on the use of state-of-the-art advances. By permitting a system developer using SHP modules to design special purpose modules (called special modules), good system design freedom results. This category of modules does not have to meet all the requirements of the SHP. The design can be flexible, within general limits, depending on the ease of installation, type of system, and condition of the development or production contract. Modules in the present system can be modified to accommodate future system developments.

SHP modules are more applicable to shipboard and shore-based systems than to avionics systems. A recent study (Reference 7) conducted by the Naval Applied Science Laboratory (NASL) had as its objective an overview of the potential applicability

of standard SHP modules (those existing SHP modules meeting all the requirements of OD 30355 and having potentially broad usage) and microelectronic techniques to a typical ASW electronics suite. The study consisted of analyzing the functional composition of a set of seven electronic equipments representative of the sub-system categories in a typical ASW system. These equipments were:

- SRC-16, Transmitter/Receiver
- SQS-26, Sonar
- SPS-43A, Radar Set
- SQS-29, Data Terminal Set
- WPN-4, Radar Navigation
- UPA-24A, Radar Display
- USQ-20, NTDS Computer.

One of the conclusions reached was as follows:

> "There is sufficient commonality of circuit functions between electronic equipments to warrant implementation of the SHP concept on a system basis. Utilization of SHP modules could eliminate design, development, and documentation of as much as 10 to 60 percent of the required functional modules for ASW equipments."

Use of existing SHP modules in avionics systems appears to be limited. Although the design inherently does not inhibit their use, except perhaps the relatively low packaging density, all but eleven of the present list of SHP modules (total: 259, as of May 1969) were designed to the Class I environmental specification. This specification calls for an operating temperature range of any of the classes of equipment in MIL-E-5400K, Reference 8. However, the use of SHP modules for an Advanced Digital Resolver being developed for the USAF is reported in the August 1969 revision of the SHP Module Matrix Chart (NAVORD Dwg. No. 2658999). Two other avionics applications are also indicated.

The generally accepted belief that reliability decreases as the functional size of modules decreases does not necessariiy apply to all packaging concepts. The picture of a large functional

module producing a more reliable system than a smaller functional module with fewer pins is tempered by the following facts:

- Failure rate of connectors is not a linear function of number of active pins.
- The number of times mating and unmating takes place affects connector reliability directly.
- Larger size modules require more mating-unmating on a per connector basis than small size modules since the increased number of circuits increases the failure rate per module.

MIL-HDBK-217A, (Reference 9) lists the following failure rates for nonenvironmental resistant connectors such as a MIL-C-21097, printed wiring board, general purpose connector:

- Static Failure Rates, λe
  - 40 active pins - 1.51 failures per 10^6 hours
  - 60 active pins - 3.92 failures per 10^6 hours
- Mating Failure Rate, λm
  - 40 active pins - .00826 failures per 10^6 hours
  - 60 active pins - .0840 failures per 10^6 hours.

Section 5 (Modularization Design Guidelines) of Reference 10 contains discussions on the modularization of microelectronic systems. The following statement is made:

> A distinguishing feature of complex electronics systems is the great number of internal signals, so that consideration of the subdivision of electronics system into constituent parts necessarily involves an examination of the number of signals which should be disconnectable in order to achieve specific goals for construction, operation, and maintenance over the service life of the equipment. If an electronic system is to take full advantage of the inherent reliability of microelectronic circuit elements the number of separable

> connectors per circuit element should be minimized because of the low reliability of this type of connections as compared to permanent connections. In addition, the disconnect terminals required for systems utilizing integrated microelectronics techniques are generally the primary determinant of overall size, maximum data rate, and minimal cost. Reduction of these parameters, therefore, requires reduction of the number of separable connections in the system by modularization. Consequently, the pertinent question in the design of microelectronic assemblies is not whether modules are to be used but rather what is the optimum module size for given usage.

An additional discussion is also contained concerning the module size and maintainability. The following statement is made:

> As the size of a module increases the probability of its being unique also increases. In the limiting case where every module in an equipment is different an entire duplicate of the equipment will be required for spares. The increase in reliability due to increase in module size and consequent reduction in interconnections must, therefore, be traded off against the increase in maintainability costs due to loss of interchangeability.

Based on available evidence, it appears that the SHP modules should not be rejected by a designer on the basis of small number of module pins. An analysis is required to determine predicted system reliability as a function of the actual module sizes and connector types proposed and the total numbers involved. The penalty of unique modules must also be considered, since maintainability is a major contributor to system availability. System maintainability using SHP modules is further enhanced by having modules which were interchangeable between systems. However, increased backplane wiring and length of signal leads also results from smaller functional size modules and should be given consideration in use of SHP modules.

(3) Cost Estimates

The cost to engineer and produce a new functional SHP module should not be significantly more than a similar planar printed circuit-type module not conforming to SHP requirements. The technologies and implementation methods involved do not appear significantly different.

There can be some cost difference between a design using the card edge connector and the SHP design requiring a two-piece module connector. However, the conventional card edge connector is less reliable than a two-piece blade and tuning fork type connector (SHP type). The SHP also provides design guidelines and thus eliminates some required design engineering analysis. It is difficult to see that the engineering costs or production costs of an SHP module result in a significantly more costly module.

The requirements for documentation, reliability, prediction, and testing of an SHP module design are contained in OD 30355, Volume I (Reference 11). These items can add significantly to the cost of a module and require some analysis. There are two categories of SHP modules. The functionally specified modules are defined by requirements and test information, but manufacturing drawings and techniques are not specified. The design disclosed modules are defined not only by requirements and test information but also by manufacturing drawings. It has been estimated that the cost of documenting a functionally specified module is twice the cost of documenting a design disclosed module. It has also been estimated that the cost to document a design disclosed module is "about the same as any other (a contractor's design) module of the same functional complexity".

Chapter 7 of Reference 11 contains the documentation requirements for SHP modules. A new SHP design begins with submission of a Design Approval Request (DAR). This DAR is required regardless of the intended category or type of module, i.e., functionally specified, design disclosed, standard, or special. The DAR includes:

- Functional application of module
- General characteristics of module

- Deviations from existing standards required by module
- Existing modules in family of stand or special modules which can be replac y this module.
- Reasons existing module or modules similar in functional design and already in the family tree cannot be used in place of proposed module.

Upon acceptance by the program, the module developer prepares and submits a preliminary Specification Control Drawing (SCD). The preliminary SCD will contain the amount of information which is available after a paper design of the module is completed and will generally be submitted prior to the evaluation of a prototype model of the module.

The documentation requirements of a design disclosed SHP module are not more stringent than those in MIL-E-16400F except that a DAR is required.

The environmental test requirements of MIL-E-16400F, Reference 12, and SHP are similar. The SHP requirements appear to be slightly more stringent. It is seldom, however, that any non-SHP module is subjected to the entire set of MIL-E-16400F tests. It would appear that some equipments procured today under MIL-E-16400F do not require the extent of testing listed at the module level. This will reduce substantially the cost of any module since the initial qualification test cost must be spread over the total number of that module produced. However, where full MIL-E-16400 testing and documentation is required at the module level, there appears to be little difference between MIL-E-16400 costs and SHP costs.

An example of functional standardization, the application of SHP modules in a hypothetical new electronic system, will illustrate cost estimating of this type of standardization.

The AN/USQ-YY computer is a new system which is now in the advanced development phase of its life cycle. It is presently described by a Technical Development Plan and will be subjected to Contract Definition prior to production of hardware for the fleet.

The program manager and his staff must make the choice between SHP functional modules and unique modules in the equipment. The following are the principal assumptions:

- Twenty-five of the systems will be produced
- Expected life of the system is 10 years
- System requirements are as follows for SHP module usage:
    - MTBF for all modules is 50,000 hours
    - Types of modules are equally distributed
    - All modules are destroy-at-failure (DAF)
    - Shipboard maintenance is pull-and-replace
    - Total of 1,000 modules is required
    - Number of module tvpes is 25
    - Twelve of the SHP module types required for the system are already in the SHP library
    - Three module types are to be designed as design disclosed (Standard)
    - Three module types are to be designed as functionally specified (Standard)
    - Seven module types are to be designed as specials
    - Average procurement cost per module is $100.
- System requirements are as follows for specially designed (non-SHP) modules:
    - MTBF for all modules is 25,000 hours

- All modules are destroy-at-failure
- Shipboard maintenance is pull-and-replace
- Total of 500 modules is required
- Number of module types is 40
- All 40 module types are to be specifically designed for system requirements
- Average procurement cost per module is $150.

- On-line test equipment requirements are the same for both means of implementation.
- Cost of enclosure and other system hardware is assumed the same
- Some other system onboard ship uses SHP modules. Of the 25 types, 5 types are used in other systems. Forty modules of each of the 5 common types are used in other systems.
- Shipboard maintenance support requirements for the system is estimated as the equivalent of one-half a technician.

The cost estimates for this example are shown in Exhibit II. As in the previous example some of the factors are not estimated, and we must assume that sufficiently accurate input information was not available. Calculations for determining initial spares requirements are in Appendix B.

The estimated figures indicate that approximately $2, 500, 000 could be saved by the incorporation of SHP standards in the system to the extent described above. None of the unestimated factors would be expected to alter the basic conclusion that adoption of the SHP system would be beneficial.

One reason that the cost savings are significant is that many existing SHP modules could be used. It was assumed that approximately 50 percent of the modules were already designed, thus resulting in substantial cost savings in the R&D phase.

LIFE CYCLE COSTS ESTIMATES FOR AN/SS(

STANDARD PACKAGING SYSTEM STANDARD

Life Cycle Phase	Cost/Performance Factor	Est Star	
		Basic	M
R&D	Module Engineering Design Costs	$7,000/ Module	I
	Module Testing Costs	$5,000/ Module (1) + $4,000/ Module (2)	6 7
	Module Documentation Costs	$10,000/ Module (3) + $20,000/ Module (4) + $ 9,000/ Module	3 3 7
	System Reliability		
	Development Time		
	Cost Bids for System R&D		
	Packaging Density		
	Contractor Reluctance		
	Partitioning Accommodation Costs	$35,000	
	Overdesign of Standard Modules		
	Performance Liability		
	Static Nature of Standard		

A

TIMATES FOR AN/SSQ-YY COMPUTER
SYSTEM STANDARD HARDWARE PROGRAM (SHP)

	Estimated Costs Standard System			Estimated Costs Non-Standard System			Estimated Gain or (Loss) By Using Standard System
	Basic	Multiplier	Total	Basic	Multiplier	Total	
	$7,000/ Module	13 Modules	$31,000	$7,000/ Module	40 Modules	$280,000	$199,000
	$5,000/ Module (1) + $4,000/ Module (2)	6 Modules + 7 Modules	$30,000 + $28,000	$4,000/ Module	40 Modules	$160,000	$102,000
	$10,000/ Module (3) + $20,000/ Module (4) + $ 9,000/ Module	3 Modules 3 Modules 7 Modules	$30,000 $60,000 $63,000	$9,000/ Module	40 Modules	$360,000	$207,000
	$35,000	1	$35,000				($35,000)

B

LIFE CYCLE COSTS ESTIMATES FOR AN/SSG
STANDARD PACKAGING SYSTEM STANDARD

Life Cycle Phase	Cost/Performance Factor	Est Star	
		Basic	N
R&D (Continued)	Maintenance of Standardization Program	$750, 000	
	TOTAL R&D PHASE NOTES: (1) Cost of qualification testing to SHP requirements. (2) Estimated cost of module qualification testing to MIL-E-16400F requirements. (3) Estimated cost to document DESIGN DISCLOSED-type SHP module. (4) Estimated cost to document FUNCTIONALLY SPECIFIED-type SHP module. (5) Number of potential programs or projects using services of functional standards.		

A

TIMATES FOR AN/SSQ-YY COMPUTER
SYSTEM STANDARD HARDWARE PROGRAM (SHP)

	Estimated Costs Standard System			Estimated Costs Non-Standard System			Estimated Gain or (Loss) By Using Standard System
	Basic	Multiplier	Total	Basic	Multiplier	Total	
	$750, 000	1/50 (5)	$15, 000				($15, 000)
e FIED- ices							$458, 000

β

LIFE CYCLE COSTS ESTIMATES FOR AN/SSQ-

STANDARD PACKAGING SYSTEM STANDARD H

Life Cycle Phase	Cost/Performance Factor	Estin Stand	
		Basic	M
PRODUCTION	Cost of Test Equipment (Shipboard and Shorebased) (6)	$10,000/ System	25
	Enclosure Production Costs		
	Time to Volume Production		
	Effects of Increased Production Competition		
	Procurement Costs	$100/ Module	1, Mo 25
	Performance Liability		
	TOTAL PRODUCTION PHASE		

NOTES:

(6) Shorebased test equipment for fault analysis purposes only.

A

TIMATES FOR AN/SSQ-YY COMPUTER
SYSTEM STANDARD HARDWARE PROGRAM (SHP)

	Estimated Costs Standard System			Estimated Costs Non-Standard System			Estimated Gain or (Loss) By Using Standard System
	Basic	Multiplier	Total	Basic	Multiplier	Total	
	$10,000/ System	25 Systems	$250,000	$12,000/ System	25 Systems	$300,000	$50,000
	$100/ Module	1,000 Modules x 25 Systems	$2,500,000	$150/ Module	500 Modules x 25 Systems	$1,865,000	($635,000)
PHASE s only.							($585,000)

B

LIFE CYCLE COSTS ESTIMATES FOR AN/SSQ-

STANDARD PACKAGING SYSTEM STANDARD H

Life Cycle Phase	Cost/Performance Factor	Estin Stand	
		Basic	Mu
OPERATION	Effects of Simplified Maintenance Manuals and Testing Procedures		
	Technician Training	$1,800/Yr. (7)	10 25 S
	Cost of Introducing New Parts in the Federal Stock System	$100/Part (9)	13 I
	Cost of Maintaining New Parts in the Federal Stock System	$50/Yr. / Part (9)	13 I x 1(
	Cost of Initial Spare Modules for Shipboard Use (10)	$20,500/ Ship (10)	25 S
	Effects of Fewer Spares on the Platform		
	Effects of Increased Competition for Spares		
	Cost of Spares Replenishment	$10,000/ Ship/5,000 Hrs. (10)	25 S 16 M of 5, Hou
	TOTAL OPERATION PHASE LIFE CYCLE COST DIFFERENCE		

NOTES:

(7) Estimated savings of 10% of training costs by use of SHP modules.

(8) Based on a cost of $10,000 to train a technician with a useful life of 2.5 years. System requires 1/2 technician.

(9) Based on data supplied by NAVELEX.

(10) 90% protection against stockout in 5,000 hours. Initial spares and spares replenishment calculations are shown in Appendix A.

A

ESTIMATES FOR AN/SSQ-YY COMPUTER
NG SYSTEM STANDARD HARDWARE PROGRAM (SHP)

	Estimated Costs Standard System			Estimated Costs Non-Standard System			Estimated Gain or (Loss) By Using Standard System
	Basic	Multiplier	Total	Basic	Multiplier	Total	
rocedures							
	$1,800/Yr. (7)	10 Yrs. x 25 Systems	$450,000	$2,000/Yr. (8)	10 Yrs. x 25 Systems	$500,000	$50,000
n	$100/Part (9)	13 Modules	$ 1,300 (9)	$100/Part (9)	40 Modules	$ 4,000	$ 2,700
m	$50/Yr. / Part (9)	13 Modules x 10 Yrs.	$ 6,500	$50/Yr. / Part (9)	40 Modules x 10 Yrs.	$ 20,000	$13,500
	$20,500/ Ship (10)	25 Ships	$512,000	$42,000/ Ship (10)	25 Ships	$1,050,000	$538,000
	$10,000/ Ship/5,000 Hrs. (10)	25 Ships x 16 Missions of 5,000 Hours Ea.	$4,000,000	$15,000/ Ship/5,000 Hrs. (10)	25 Ships x 16 Missions of 5,000 Hours Ea.	$6,000,000	$2,000,000
HASE ENCE of SHP th a use- ian. itial shown							$2,604,200 $2,477,000

B

The assumption was made that all modules in the system would be destroy-at-failure while the system was in fleet use. This gives an advantage to the SHP module as they are less costly than those uniquely designed for the computer. It is anticipated that some repair would be economical in both the SHP and special design cases. This would reduce the cost for replacement modules but repair facilities and additional parts would have to be considered.

3. METHODOLOGICAL STANDARDIZATION APPLICATIONS

The CCC module concept is an example of methodological standardization. The size and number of circuits of the modules are a direct function of the requirements of the CCC portion of the IHAS. The importance of the CCC module concept as a Navy benchmark standard is in the packaging techniques and methods used in the CCC implementation, not in the use of the exact module sizes or functional module partitioning used. Many of the performance factors of methodological standardization are similar to those of mechanical standardization.

Of the industry personnel interviewed, only personnel of an aircraft manufacturer were familiar with the details of the CCC module design. Their comments were favorable for the design techniques used and consideration was being given to use of CCC modules in a current avionics application.

The mechanization techniques developed under the Integrated Helicopter Avionics System (IHAS) program are the items that should be considered as potential benchmarks as defined in NAVMAT P3940. These techniques result in high packing density, minimum space and weight, and apparently high reliability and are more applicable to airborne equipment. To be included as a benchmark, complete test results or actual field experience should be made available and more detail of the packaging techniques described should be disclosed.

IV. SELECTION AND IMPLEMENTATION OF STANDARDIZATION REQUIREMENTS

Widespread acceptance and implementation of SHP, EPS, or any other standard cannot be accomplished until Navy project management personnel are convinced that standards are beneficial. Once the applicability of a packaging standard to a project has been established, either by operations research techniques or less formal procedures, steps toward implementation can be taken. A key to successful utilization of a standard to any system will be the extent of participation by a group within CNM which is chartered, staffed and funded to provide this assistance to project personnel.

1. EVALUATION OF PACKAGING STANDARDS APPLICATION

The methods used to evaluate the applicability of a packaging standard will vary with each project or system. In many cases, the question will be entirely one of money as it will be relatively simple to establish that either the standard or the nonstandard packaging concept under consideration will meet all operational performance requirements. In these cases, simple cost balance sheets, as portrayed in Exhibits I and II in the previous section, will provide the answer.

More complex systems, especially those which are early in the development cycle, will require other procedures to determine packaging standard applicability. The classic operational research methods are described in detail in numerous texts and papers and need not be developed here. It is sufficient to note that these methods normally consist of ranking/weighting system for five general evaluation factors: reliability, maintainability, cost, weight, and volume. Weights are assigned to each of these factors depending on relative importance to the system and the candidate package design is assessed by examining each of its aspects which contribute.

An OR technique well suited for the evaluation of packaging standard applications is described in "Handbook of Design Criteria for Microelectronic Systems Packages" (Reference 10). Personnel skilled in the application of these techniques must be made available to assist Project Managers where necessary.

2. THE PROJECT MANAGER'S ROLE IN EVALUATION

Each project manager or pro ·ct engineer who considers the potential application of some type of ·ckaging standardization must perform his own evaluation. It is u ·ikely that anyone outside the project group, especially in the R&D hase of the project, would have the data and the life cycle overview o. the subject to make such a judgement. It is important that this project expertise be supplemented by specialists who understand the details and application of standardized design.

A quick look at life cycle cost factors is one of the first steps in determining potential applicability of a standard. One method of doing this is described earlier in this report and is presented in Exhibits I and II. Assessments such as these do not pretend to be detailed accountant's balance sheets but are extremely valuable as the first examination of the effects of the standard on cost.

3. EXPECTED INDUSTRY RESISTANCE TO STANDARDS

The requirement that a functional or mechanical packaging standard be applied can seldom be interpreted as an incentive to industry. If a program is in its early stages and industry is assisting in the design and development of a system (such as in Contract Definition) the imposition of a standard may be considered restrictive to the design effort. If prototype hardware is to be procured, extensive implementation of a standard may eliminate one of industry's traditional tactics: underpricing or "buy-in" on the prototype hardware which incorporates highly unique packaging so that the development contractor will have a preferred position in bidding on subsequent production runs.

Packaging standardization is usually viewed by industry as a constraint when RFQ's for production quantities of equipment are issued. Cost cutting becomes more difficult and competition more intense when standards are extensively applied.

These factors, unattractive as they are to industry, work in the Navy's behalf. Greater cost savings, better performance and more prompt delivery may be expected. Therefore, the only incentive to industry is the implicit promise that a fair agreement will be made with the company who has offered the most advantageous contract to the Navy. Because of packaging standardization the Navy's ability to determine which contract is the best should be greatly improved.

4. ESTABLISHMENT OF A PACKAGING STANDARDS GROUP IN CNM

A packaging standardization group should be organized to assume the responsibility of managing all the current benchmarks contained in NAVMAT P3940 (including the current SHP) and aiding the separate project managers/engineers in determining the applicability of the standards to each system's requirements. Publication of a design guidelines manual alone will not be widely effective. Unless there is a permanent, active group to seek out project managers/engineers who can effectively use the benchmarks standards, the intended mission of this manual (NAVMAT P3940) will not be accomplished, nor will the Navy reap the full benefits of standardized packaging.

This packaging standardization group should have the responsibility and authority to perform the following tasks:

- Actively solicit project managers/engineers on those programs and projects which can benefit from use of a standard packaging system. The group should have systems engineers that can work directly for project managers when assigned at the project level.

- Reinforce the NAVMAT P3940 benchmarks by making sure that no concept is included that has not been proven from environmental, performance, and availability standpoints.

- Coordinate the failure reporting system on those electronic systems designated benchmarks.

- Establish an updating program that will continually search for and evaluate new or proposed packaging systems as potential Navy standards.

- Develop complete technical data packages containing all the engineering and assembly drawings, MTBF data, and qualified sources for all the benchmarks. This data package should allow contractors bidding on systems to estimate the cost and performance of the benchmark(s) spelled out in the RFP/RFQ.

- Refine the criteria for benchmark selection presented in this report and further define the life cycle cost estimating concept presented by application to specific systems entering the R&D phase.

The cost of running a packaging standardization program which could effectively implement packaging standardization has been estimated at approximately $850, 000 annually. Actual costs to the CNM budget may vary, depending on the size and scope of the group, but the program goals can be effectively achieved only through an active, funded, and coordinated program.

Standardization would be accelerated if individual projects do not have to bear all the costs for initiating packaging standardization in their equipments. Funding procedures should be flexible enough to allow some extra expenditures for standardization in initial procurement when ultimate savings appear probable.

The higher estimated cost for proper documentation of a functionally specified, standard SHP module should not necessarily be borne directly by the contractor under which it was developed. By definition, this type of module is projected to be useful in other functionally independent systems. Therefore, some part of this cost should come from the operating funds of the packaging standardization group, which has assumed the responsibilities of the current SHP. This may not be required where the system development is a large one requiring multiple contractors all under control from one project office.

5. STANDARDS AS REQUIREMENTS IN GOVERNMENT CONTRACTS

It is evident that packaging standards will not be widely applied unless they are included as a requirement in the procurement document. If a Navy Project Manager is convinced that application of a standard will be in the best interest of his program, a comprehensive statement of the Navy's intent to implement in the procurement is essential. The RFP/RFQ should include:

- Complete identification of the standard to be implemented. This would include drawings, specifications, and all other documents necessary.

- A clear statement on the extent of application of the standard packaging system. If some subsystems

or components of the equipment are not suitable for the standard (i.e., dish antennas, antenna mounts, displays, etc.) they should be identified.

- A clear statement on the acceptability of alternate proposals. The bidder should know whether the receipt of a proposal containing his or a competitor's proprietary packaging system will be considered responsive.

- A statement of the extent of contractor performance liability. This is difficult as all of the problems may not be foreseen at the time of issuance of the RFQ. However, the Navy should attempt to fix areas of responsibility in case of nonperformance of standard hardware.

- Proposal evaluation criteria. This is somewhat related to the question of the acceptability of alternate proposals. The importance of implementing the specified standard must be stated in a manner which can be easily assessed by the potential contractor.

There are undoubtedly other contractual aspects of the use packaging standards which will be important in individual cases. One measure of the success of the group described in the previous section will be its ability to develop those contractual features which will eventually result in the greatest benefit to the Navy.

V. CONCLUSIONS AND RECOMMENDATIONS

1. CONCLUSIONS

- The application of appropriate packaging standards concepts represents a large potential dollar saving for the Navy.
- Widespread adoption of standards may also result in a general improvement in systems performance characteristics.
- The mechanical system (EPS) and the functional concept (SHP) described in NAVMAT P3940 appear to be most suitable for broad application.
- The potential cost savings from the use of a functional standard, such as SHP, are much greater than from the use of a purely mechanical standard, such as EPS.
- The similarity between the Centralized Electronic Control (CEC) packaging system and the Electronic Packaging System (EPS) make their mutual inclusion in NAVMAT P3940 seem unnecessary.
- Current SHP modules can be used effectively in most electronic systems which are principally digital and installed on surface ships, submarines, or shore bases.
- Complete performance and environmental test results/ field experience should be evaluated for the Central Computer Complex (CCC) before it is considered as a standard.
- The unique packaging requirements for most airborne electronic systems preclude the use of a mechanical

standard except for the mechanical interfaces at the Weapons Replaceable Assembly (WRA) level. Methodological standardization is more suitable for airborne systems than either mechanical or functional standards.

- Suppliers and users have reservations about the use of the present standards. Many believe that:

  - EPS is overdesigned for general shipboard use.

  - The Preskam connector is too expensive.

  - SHP requires excessive costs to engineer, produce, test and document new modules.

  - Reliability problems may develop in SHP applications due to excessive number of connector pins.

- Each system/module must be evaluated individually in terms of adaptability to standardized electronic packaging, life cycle costs, and performance factors.

- Assessment should be made by project personnel with assistance from CNM packaging specialists.

- The group designated to assist project personnel in application of standards to their designs must be adequately chartered, funded, and staffed.

- Life cycle cost estimates made on available information is usually adequate to show gain or loss expected by implementation of standards concepts.

- Maximum cost effectiveness will result from those standardized items which are produced and used in large quantities.

- Standards will be used widely only if specified in procurement documentation.

- Use of packaging standards will be promoted if the costs for developing and maintaining standard modules and enclosures are borne by special CNM funding.

2. RECOMMENDATIONS

- A CNM packaging standardization organization should be initiated to coordinate and assist projects and programs in the effective use of current benchmarks contained in NAVMAT P3940. This group should assume the responsibilities and authority outlined in Chapter IV, Section 4 of this report.

- The multitude of documents and reports concerning the Navy standards should be listed in a revised NAVMAT P3940 or similar manual.

- Further study should be initiated to determine the requirements for additional Navy packaging standards and to explore the potential of those in-house packaging systems discussed in this report, and of other commercial systems.

- A comprehensive statement of the Navy's intent to implement a packaging standard in a procurement is essential. The RFP/RFQ should include:

  - Complete identification of the standard, including drawings, specifications, etc.

  - Level and/or subsystems affected.

  - Statement on alternate proposals.

  - Extent of contractor performance liability.

  - Proposal evaluation criteria.

- More information concerning the tradeoff values used during the development of NAVMAT P3940 standards should be made available in a revised edition. Data on size, weight, volume, cost, interconnection, complexity, maintainability, reliability, etc., factors would aid potential users in determining the applicability of the established standard modules to their particular system development. The industry reservations mentioned earlier should be given due consideration in making the revision.

- Special funding should be provided to augment project funding where initial costs of standardization may be heavy but the life cycle pay-back is high.

- A continuing program to publicize the desirability of implementing packaging standards is needed and should be begun. Project Managers should be encouraged to:

  - Request the latest information on packaging standards.

  - Determine if there is a potential application in their systems.

  - Ask for NAVMAT STDS Group help to:

    - Evaluate cost and performance factors
    - Prepare procurement documentation
    - Apply specific design details.

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Mr. Carl Heffernon, Raytheon Company, Submarine Signal Division, Portsmouth, Rhode Island

Mr. Mark Mellinger, Grumman Aircraft Engineering Corp., Bethpage, New York

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DEFINITION OF TERMS

Terms and abbreviations which are used in this report are defined below for reference.

Term/Abbreviation	Definition
Backplane	The side of the rack which is generally used for wiring interconnections between modules, and which is normally opposite the side of the rack from which modules are removed and replaced.
Benchmarks	Preferred packaging designs which serve as a reference base against which the effectiveness of all designs are compared.
CCC	Central Computer Complex - A benchmark packaging standard in NAVMAT P3940 developed by NADC.
CEC	Centralized Electronic Control - A benchmark packaging standard in NAVMAT P3940 developed by NRL.
Chassis	The physical structure which retains and electrically interconnects a group of modules which perform higher level functions.
Discrete Components	Individually packaged components, such as resistors, transistors, capacitors, etc.
EPS	Electronic Packaging System - A benchmark packaging standard in NAVMAT P3940 developed by NELC.

Term/Abbreviation	Definition
Enclosure	A combination of the external housing and the racks.
Functional Standard	Refers to an electronic circuit function performed by a module or assembly that can be used in more than one system.
Hybrid Circuit	Two or more circuit fabrication techniques in combination with each other to form a circuit function; such as integrated circuits in combination with discrete components, or integrated circuits attached to thin film circuits.
IC	Integrated circuit.
IHAS	Integrated Helicopter Avionics System
Installation	The vehicle, shelter, building, aircraft or other site in which the individual electronic packages will be installed for use, including structure, air conditioners, heaters, connections between packages, etc. the highest mechanical assembly level in a packaging system.
Integrated Circuit	The physical realization of a number of electric elements which are entirely in the form of thin film deposited in a patterned relationship on a structural supporting material; or which are inseparably associated on or within a continuous body of semi-conductors to perform the function of a circuit.
Mechanical Standard	Refers to a complete packaging system or major portion of, other than the electronic circuit elements or circuits, that can be used in more than one system.
Microelectronics	Electronic circuitry based on the solid state physics of semi-pure materials arranged in extremely compact geometrics.

Term/Abbreviation	Definition
Module	A readily replaceable structural unit which is designed for the containment and/or mechanical support of one or more electronic components or circuits, and which may be configured only in discrete, predefined, dimensional increments.
Multilayer	A three-dimensional circuit built up of printed circuits bonded together and interconnected through the laminates.
NAD Crane	Naval Ammunition Depot, Crane
NADC	Naval Air Development Center
NASL	Naval Applied Science Laboratory
NAFI	Naval Avionics Facility, Indianapolis
NAFI Modules	Same as SHP Modules
NELC	Navy Electronics Laboratory Center
NRL	Naval Research Laboratory
Packaging System	The mechanical and electronical devices which must be combined with circuits in order that they maintain their integrity when exposed to a specified environment.
Printed Circuit	A pattern comprising printed wiring and printed elements, forming a predetermined design in, or attached to, a surface or substrate.
Printed Contact	That portion of a printed circuit used to connect the circuit to a plug-in receptacle and to perform the function of a pin in a male plug.

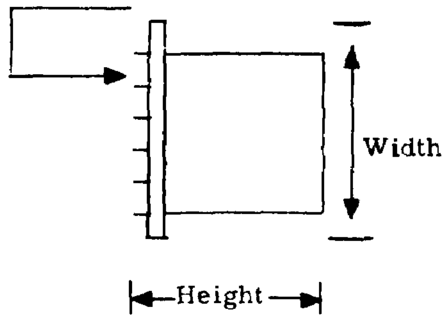
Term/Abbreviation	Definition
Rack	The mechanical support for the chassis, interconnecting cables, modules, front panel performance monitoring devices, and adjustment controls.
Serviceable Main Chassis	NELC designation equivalent to rack as used in NAVMAT P3940.
SHP	Standard Hardware Program.
SHP Modules	A benchmark packaging standard in NAVMAT P3940 developed by NAFI.
WRA	Weapon Replaceable Assembly.

APPENDIX A

PACKAGING CONCEPT: ELECTRONIC PACKAGING SYSTEM (EPS) (NELC)
MODULE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
General Description of Modules	The EPS modules are part of a total integrated packaging system. There are two types which are constrained both dimensionally and thermally. The two types are a printed circuit (PC) board assembly with edge board connectors and a shielded module (SC). The shielded module consists of a six-sided rectangular shield mounted onto a connector plug. A special PC module design is also available for mounting of high-current circuits. All EPS modules are specified dimensionally and mechanically only.	Reference 2 See page 1-2h, Item II-3
Circuit Technology or Application Restrictions	The PC-1 module is designed around planar, solid state technology and is intended for mounting of digital and low-power linear circuits. The PC-1 module can also be used to mount discrete components. The PC-10, -20 module is intended for line regulator and power driver circuits. The SC-1 module is intended for circuits requiring electrical isolation and coaxial cable connectors or single conductor connections. Circuit technology is not restricted.	Reference 2

PACKAGING CONCEPT: ELECTRONIC PACKAGING SYSTEM (EPS) (NELC)
MODULE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS			DATA SOURCE
Module Size Connector Pins  	PC-1 Module (Inches) Width 4.0 Fixed Height* 3.8 Min. (Pref.) 7.6 Max. Thickness 0.6 (Pref.) 0.2 Incre. 1.2 Max.	PC-10, -20 Modules (Inches) Width 4.0 Min. (Pref.) 2.0 Incre. Height* 3.8 Min. 7.6 (Pref.) Thickness Not Specified	SC-1 Module (Inches) Width 4.0 Min. (Pref.) 2.0 Incre. 12.0 Max. Height* 3.8 Min. 7.6 Max. (Pref.) Thickness 0.8 Min. (Pref.) 0.8 Incre.	Reference 2
	* Includes Approximately 0.4 of Wiring Space			
Packaging Efficiency $\left(\frac{\text{Total volume of module}}{\text{Volume of circuits}}\right)$	Varies			

PACKAGING CONCEPT: ELECTRONIC PACKAGING SYSTEM (EPS) (NELC)
MODULE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Cooling Methods Design	Modules are cooled by forced air convection cooling. Cooling air is blown over the module area containing the components, via ducting in the horizontal module supports. Each module receives its own individual supply of cooling air.	Reference 1
Power Density	Maximum heat dissipated by electronic components in the SC and PC modules was established at 0.5 watts per square inch for PC-1 modules.	NELC
Pin Count and Spacing	PC-1 Module: 58 pins on 0.100-inch centers or 114 pins on 0.050-inch centers. PC-10, -20 Modules: 32 contacts, 16 on a side, 0.187-inch center or 16 contacts, 0.187-inch centers. SC-1 Module: A family of four connector shells with small and large cavities, contacts are removable (see page 6-47, Ref. 1 for details)	
Type of Module Connector (Interface)	PC-1: A cam-actuated locking device (Preskam) exerts a clamping pressure along the printed circuit card edge connector. PC-10, -20: Card edge connector SC-1: Plug-in receptacle with additional jack screw locking device.	

PACKAGING CONCEPT: ELECTRONIC PACKAGING SYSTEM (EPS) (NELC)
MODULE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Insertion-Withdrawal Force	PC-1: Essentially zero when locking device is opened, clamping force in locked position. Tested to meet MIL-S-901, MIL-STD-167, with no contact intermittance. PC-10, -20: See NELC. SC-1: See NELC.	
Type of Module Design	PC-1: Planar printed-circuit board PC-10, -20: Planar printed-circuit board SC-1: Determined by module function.	
Intermodule Wiring Scheme	PC-1: Solder, welded or wire-wrapped terminations, nonremovable contacts. Capability of having test points installed on the termination (backplane) side of connectors. PC-10, -20: Screw and crimp lug termination, removable contacts. SC-1: Plug and receptacle, removable contacts.	
RFI-EMI Shielding Design	PC-1, -10, -20: Not included in module design. SC-1: Purpose of module; shielding effectiveness determined by construction of module shielding.	

PACKAGING CONCEPT: ELECTRONIC PACKAGING SYSTEM (EPS) (NELC)
MODULE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Module Keying or Indexing Scheme	PC-1: Polarizing slots on the PC boards, keying configurations by equipment designer. SC-1: Polarization is achieved by design of guides and keying by location of contacts.	
Module Complexity (Level of Electronic Function)	Determined by system partitioning and heat dissipation requirements.	
Module Repair Level	The PC module may be repairable but is considered to be simply replaceable under operational conditions. May be designed as a destroy-at-failure unit.	Reference 2
Module Reproducibility	A function of circuit design.	

PACKAGING CONCEPT: ELECTRONIC PACKAGING SYSTEM (EPS) (NELC) ENCLOSURE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
General Description of Enclosure Design Features	The EPS includes a family of free-standing enclosures. The family includes four basic types of enclosures and three types of vertical serviceable chassis and one horizontal drawer-like chassis. Module replacement and access to backplane wiring is accomplished from the front of the enclosure. Each enclosure is a separate entity, providing all necessary enclosure functions. Each chassis has its own latching mechanism.	Reference 2
Weight of Enclosure (Excluding Electronics Payload)	See Table B-1, NELC Enclose Weights	
Sizes of Enclosures and Chassis	Outside dimensions of all four enclosures: 24 inches wide, 25 inches deep, and 72 inches high. (The total enclosure has one of four designations which depends on the chassis configuration) Serviceable Chassis (called Racks in NAVMAT P3940) Type I - A vertical chassis 7.88 inches wide; two of these chassis are used in Type A or Type C enclosure. Type II - A vertical chassis consisting of two 3.88-inch frames with one hinged to allow access to both frames. Type III - A vertical 17.5-inch chassis, mounted in the Type B enclosure. No Designation - A horizontal drawer of various heights; 3.5-inches high front panel minimum, also 7, 10.5, and 14 inches.	Reference 1

PACKAGING CONCEPT: ELECTRONIC PACKAGING SYSTEM (EPS) (NELC) ENCLOSURE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Chassis Design Features	All serviceable-chassis vertical supports contain ducts for cooling. The top of each chassis is allocated to wiring entering and leaving the chassis. The Type I and II chassis are designed to support a 400-pound load. The Type III supports an 800-pound load. The latching mechanism provides four intermediate locking positions as well as fully closed and open. Additional intermediate stops can be provided, and an infinite position locking is also available. The serviceable-chassis slides allow extension of the chassis to 30 inches.	Reference 2 and NELC
Heat Transfer Units and Features	The EPS preferred cooling system is based on forced air (filtered) convection cooling, with the water-cooled-refrigerant vapor-compression-cycle method used to cool the air. A thermal control module and associated control unit for each of the three enclosures containing vertical chassis are being developed. A thermoelectronic unit is being developed, and a water-to-air exchanger is also available. The three cooling capacity sizes of thermal control units are: . 1300-watt intended for each serviceable chassis of the Type A enclosure. . 2600-watt intended for the Type C enclosure. . 5000-watt intended for the Type B enclosure. Cooling air is provided in all maintenance positions of the serviceable chassis.	Reference 2

PACKAGING CONCEPT: ELECTRONIC PACKAGING SYSTEM (EPS) (NELC) ENCLOSURE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Inter-Rack (Chassis) Cabling Features	The serviceable chassis provides wiring ducts for routing of intermodule wiring in the chassis frame. For input/output between chassis, wiring is brought up to the top to a plug and receptacle with crimp-type contacts. Up to 28 of these inter-racks connectors can be mounted abreast the top of the serviceable-chassis. Connection to the enclosure interface (junction box) or other chassis is made by flat cable through another rectangular flat cable connector at the top of the back panel of the enclosure. The EPS program stresses the use of flat cable for chassis interface where electrical parameters permit. See Chapters 5 and 6 of Reference 2 for details of wiring and connectors, and NELC Drawing Sketch No. SK3360F-699, Sheet 2.	Reference 2 and NELC
Interenclosure Cabling Features	The method of interenclosure wiring or interfacing with other ships systems is via a junction box available in lengths of 22, 40, and 58 inches. The box is mounted on the rear of the enclosure. The junction box is 8 inches deep and may be removed for enclosure installation. The enclosure connectors are bulkhead-type and provide interface connection between ships armor cable and the flat interchassis cable. See Chapters 5 and 6.	Reference 2

PACKAGING CONCEPT: ELECTRONIC PACKAGING SYSTEM (EPS) (NELC)
ENCLOSURE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Volumetric Efficiency $\left(\frac{\text{Volume of Payload}}{\text{Volume of Enclosure}}\right)$	A Type A enclosure with two Type II chassis can accommodate 1020 PC-1 modules of the preferred type. With integral cooling units it will accommodate 708 PC-1 modules of the preferred type.	Reference 2
Gravimetric Efficiency $\left(\frac{\text{Weight of Payload}}{\text{Weight of Enclosure and Payload}}\right)$	See Table B-1.	
RFI-EMI Shielding Design	A combination RFI and moisture-proof gasket is provided for each chassis or access opening in the enclosure.	Reference 1
Mounting Provisions and Area Required	The enclosure is designed to be hard mounted in any shipboard compartment and requires fastening through the base of the enclosure only. It requires no side or top bracing. Mounting area required: Approximately 2 ft. x 2 ft. Volume required: Approximately 24 cubic feet. Front Clear Area Required for maintenance: 2.5 ft. x 2 ft. Junction Box Area required: 8 x 19 inches.	Reference 2

PACKAGING CONCEPT: ELECTRONIC PACKAGING SYSTEM (EPS) (NELC)
ENCLOSURE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Enclosure Components Producibility	Type A - Production evaluation completed, tooled for large quantity (volume) production. Type B - Production drawings completed, tooling required to fabricate Type III chassis. Type D - Production drawings completed, pre-production contract pending.	NELC
Displays and Controls Mounting Features	A limited amount of space is available on the serviceable chassis doorfront for displays and controls. However, depth behind front panel may be extended from front of serviceable chassis.	NELC
Prior Qualification to Military (Navy) Operational Environments	The enclosure system has met the environmental requirements of MIL-E-16400.	Reference 1
Use of Packaging Concept in Systems and Equipments	Complete enclosure system is not in operational system (as of 8/69). Part of the EPS is being used aboard the USS OKLAHOMA CITY in the automated Message Processing and Distribution System (MPDS), also two enclosures as part of CCM of CVAN-68 NIMITZ. It is also proposed for packaging as part of Project SHORTSTOP.	Reference 1

PACKAGING CONCEPT: ELECTRONIC PACKAGING SYSTEM (EPS) (NELC) ENCLOSURE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Design Documentation Status	The basic source of information concerning the EPS is Integrated Packaging Manual for Shipboard Electronic Systems and Equipments, (latest revision 1 May 1967). (This is Reference 2 referred to in Data Source column of this chart.) Other reports are available concerning various design tradeoff studies, performed in support of the EPS design. Assembly drawings are also available.	
Sources of Packaging Concept Components	All components of the EPS are available from the respective manufacturer as a fabricated item or are supported by drawings. Reference 2, Appendix A, gives a list of the manufacturers of the various components. Production tooling, in most instances, is owned by the Navy. Manufacturers of proprietary items are committed to licensing.	Reference 2
Cost of Packaging System Components	Contact NELC.	NELC
Availability of Packaging System Components	Contact NELC.	NELC

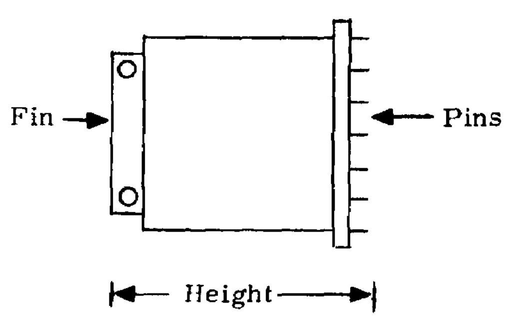
PACKAGING CONCEPT: ELECTRONIC PACKAGING SYSTEM (EPS) (NELC)
DESIGN CRITERIA

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Brief History of Concept Development	The EPS evolved from efforts done in 1964 on development of optimum packaging techniques for the Navy Shipboard Advanced Communication Systems (NSACS). NEL extended this effort by designing into the EPS methods of correcting packaging system faults observed in environmental evaluations of various other packaging systems.	
Design Philosophy	The EPS design is a totally integrated packaging system embracing modules, cooling, connectors, wiring schemes, and other enclosure hardware. Design objectives were to develop a complete packaging system which is versatile and flexible and meets all interface and environmental requirements for Navy shipboard use. System reliability and maintainability were overriding design considerations.	
Design Applicability for Navy Electronic Systems	The EPS was designed specifically for Navy surface shipboard use. It can be used in all shipboard compartments. Enclosure sizes do not permit ready use in submarines. However, a design capable of being disassembled is available for submarine installation.	Reference 2 and NELC

PACKAGING CONCEPT: ELECTRONIC PACKAGING SYSTEM (EPS) (NELC)
DESIGN CRITERIA

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Name of Developing Agency or Company	The EPS was developed at the Navy Electronics Laboratory (NEL).	
Group or Individual to Contact for Additional Information	Code S340 U.S. Navy Electronics Laboratory Center San Diego, California 92152	

PACKAGING CONCEPT: EVALUATION CRITERIA - STANDARD HARDWARE PROGRAM MODULES (NAFI)
MODULE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
General Description of Modules	The SHP modules are a family of functionally (electronic), dimensionally, and mechanically specified plug-in-replaceable elements. Each module performs a particular electronic function. The function is either explicitly specified or the design is disclosed.	
Circuit Technology or Application Restrictions	Module is designed around planar, solid state technology. Reliability specification negates anything other than solid state components. Applications are low and medium power analog and digital circuits. AN/BQG2A modules are tested at 20 Mcps. 60 Mcps I. F. amplifier is also in family.	Reference 1 and NAFI
Module Size 	Basic Size: 2.62 inches wide, 1.95 inches high (module fin-to-pin dimension), and 0.290 inches thick. Modules may be made in multiple span and thickness as follows: Span (width) - Increments of 3.0 inches Thickness - Increments of 0.3 inches	Reference 11

PACKAGING CONCEPT: EVALUATION CRITERIA - STANDARD HARDWARE PROGRAM MODULES (NAFI)
MODULE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Packaging Efficiency $\left(\frac{\text{Total Volume of Module}}{\text{Volume of Circuits}}\right)$	Varies with module type.	
Cooling Methods Design	Cooling fin in multiple increment modules. Extraction fin, card guide, and pins provide the primary conductive heat paths. The module design does not permit forced air convection cooling directly over circuit components. Forced air convection over the heat fin and mounting structure was the method considered in the initial design. However, free air convection through heat fin and conduction through module supporting structure can be used to control fin temperature.	Reference 11
Power Density	Generally a maximum of 0.75 watts/sq. in. of module fin surface. Basic module power density is 1.5 watts.	OD 30355 Reference 11
Pin Count and Spacing	Basic module: 40 pins on 0.100 inch centers in two rows of 20 pins. Modules generally have from one to four rows (80 pins maximum desirable due to insertion force).	Reference 11
Type of Module Connector (Interface)	The module header connector is a blade type (male) mating with a tuning fork contact. The other end of this tuning fork provides the intermodule backplane connection means.	Reference 1

PACKAGING CONCEPT: EVALUATION CRITERIA - STANDARD HARDWARE PROGRAM MODULES (NAFI)
MODULE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Insertion-Withdrawal Force	12 oz. maximum inserts per module contact; 2 oz. minimum withdrawal	Reference 1
Type of Module Design	Generally planar printed-circuit board. Packaging technology lends itself to any technique, e.g., thick film, thin film.	NAFI
Intermodule Wiring Scheme	Back panel wiring techniques are left to the system user.	Reference 1
RFI-EMI Shielding Design	Intermodule shielding is not included in the basic SHP module design. However, several equipments have modules utilizing shielded module design.	Observation and NAFI
Module Keying or Indexing Scheme	Two keying pins per module provide a total of 120 possible unique keying configurations.	Reference 11
Module Complexity (Level of Electronic Function)	An objective of the SHP is the design of modules containing basic and complex electronic functions which can be used effectively in a variety of applications.	Reference 11
Module Repair Level	The level preferred by the SHP is a throw-away type maintenance procedure once the fault is located in a particular module.	Reference 11
Module Reproducibility		

PACKAGING CONCEPT: EVALUATION CRITERIA - STANDARD HARDWARE PROGRAM MODULES (NAFI)
MODULE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
General Description of Enclosure Design Features	No one method is specifically required for mounting of SHP developed modules.	
Weight of Enclosure (Excluding Electronics Payload	Not applicable (N/A).	
Sizes of Enclosures and Chassis	N/A	
Chassis Design Features	N/A	
Heat Transfer Units and Features	N/A	
Interrack (Chassis) Cabling Features	N/A	
Interenclosure Cabling Features	N/A	
Volumetric Efficiency	N/A	
Gravimetric Efficiency	N/A	
RFI-EMI Shielding Design		
Mounting Provisions and Area Required		
Enclosure Components Producibility	N/A	
Displays & Controls Mounting Features		

PACKAGING CONCEPT: EVALUATION CRITERIA - STANDARD HARDWARE PROGRAM MODULES (NAFI)
LIFE-CYCLE COSTS

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Prior Qualification to Military (Navy) Operational Environments	The environmental specification for SHP modules is comprised of selected individual military requirements allowing potential application to a wide spectrum of military systems. There are two independent environmental classes based on separate module fin temperature and vibration levels. See OD 30355, Volume I, Chapter 5, for environmental requirements.	Reference 11
Use of Packaging Concept in Systems and Equipments	Operational Systems: None (as of 9/68). Pre-Production Systems/Equipment: The two largest systems are the POSEIDON FCS, MK 88, and the Torpedo FCS, MK113, Mod 9. See page 1-2.5 of OD 30355, Volume I for complete list of systems/equipments using SHP modules.	Reference 11
Design Documentation Status	All modules have complete design documentation. There are also a large number of other documents pertinent to the SHP. Refer to OD 30355, Volume I, Chapter 7, and Appendix E for documentation requirements and sources of the various documents.	Reference 11

PACKAGING CONCEPT: EVALUATION CRITERIA - STANDARD HARDWARE PROGRAM MODULES (NAFI)
LIFE-CYCLE COSTS

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Sources of Packaging Concept Components	In general, there are multiple sources of supply of module hardware components. Refer to OD 30355, Volume III, Chapter 8 for listing. The sources of complete modules are contained in NAVORD Drawing No. 2658999 for special modules and standard modules. These drawings are titled SHP Module Matrix Charts. Many complete modules have multiple-qualified vendors.	Reference 11
Cost of Packaging System Components		
Availability of Packaging Concept	In general, module hardware components are readily available from commercial sources, as are most complete standard modules.	

PACKAGING CONCEPT: DESIGN CRITERIA - STANDARD HARDWARE PROGRAM MODULES (NAFI)
MODULE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Brief History of Concept Development	In the early 1960's, the Navy began a study at NAFI to determine what could be done to curtail the continuous proliferation of electronic equipments containing similar functional circuitry, but with little or no electrical or mechanical standardization. This effort resulted in initiation of the Standard Hardware Program (SHP). The object of the SHP is to develop a family of functional electronic plug-in modules to serve as common building blocks from which systems engineers can construct a variety of complex electronic systems.	Reference 11
Design Philosophy	Development of modules under the SHP has as an ultimate goal a module that is functionally specified and is thrown away at failure. The module dimensions were determined by using the following criteria: . Amount of circuitry required to perform a specific electrical function. . Maximum number of interface connections these required. . Size of the keying and hold-down mechanisms. . Maximum tolerable cost for the module to be considered a throw-away item.	Reference 11

PACKAGING CONCEPT: DESIGN CRITERIA - STANDARD HARDWARE PROGRAM MODULES (NAFI)
MODULE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Design Applicability for Navy Electronic Systems	The SHP modules have been developed primarily for use on Navy ship and shore equipments; however, there have been modules developed for use in avionics equipments.	
Name of Developing Agency or Company	The SHP was initiated at the Naval Avionics Facility (NAFI).	Reference 11
Group or Individual to Contact for Additional Information	Commanding Officer Naval Avionics Facility 21 St. Street and Arlington Avenue Indianapolis, Indiana 46218 Attention: Code D924	Reference 1

PACKAGING CONCEPT: EVALUATION CRITERIA - CENTRAL COMPUTER (NADC) COMPLEX (CCC) MODULE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
General Description of Modules	The CCC is one part of the Integrated Helicopter Avionics System (IHAS). The design of the CCC modules represents a concept of packaging integrated circuit dice or chips on a medium scale basis. A single substrate with up to 34 IC's is the functional package contained in a space of 0.75 x 1 x 0.90 inches. Up to 24 of these chips are grouped together to form a plug-in module with a module consisting of 4 submodules mechanically connected. The CCC circuitry is made up of 48 different substrates utilizing only 8 different circuit dice in various combinations.	Reference 1
Circuit Technology or Application Restrictions	The CCC module is designed specifically to package digital integrated microelectronic circuits on a medium scale integration (MSI) basis. This complex packaging technique is useful in applications where extreme constraints exist on volume, weight and power dissipation, such as airborne installations.	
Module Size	All modules are the same dimension (in inches). Width 6.724 · Height 1.5 · Thickness 0.4	Reference 1
Packaging Efficiency $\left(\frac{\text{Volume of Circuits}}{\text{Total Volume of Module}}\right)$	Extremely high.	

PACKAGING CONCEPT: EVALUATION CRITERIA - CENTRAL COMPUTER (NADC) COMPLEX (CCC)
MODULE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Cooling Methods Design	Modules are cooled by conduction of heat through the submodule aluminum mounting frames to a heat exchanger in the cover of the housing. Forced air over the "cold plate" heat exchanger convects the heat away from the unit housing.	Reference 1
Power Density	(Unknown)	
Pin Count and Spacing	Each module has 288 pins in 4 rows of 72 pins with a spacing of 0.075 inch centers.	Reference 1
Type of Module Connector (Interface)	The module connection to the housing motherboard is by pin and socket.	
Insertion-Withdrawal Force	Module removal is accomplished by engaging two small screw driver tips into slots on the retaining chips of the module. A series of these slots provides a step removal action and reduces the high removal forces required by 75 percent.	Reference 1
Type of Module Design	Module design is planar, medium scale integration of microelectronic digital circuitry.	
Intermodule Wiring Scheme	Wire-wrap is used exclusively to electrically couple the module receptacle pins and the motherboard split pin halves. There are no jumpers. All intermodule wiring is accomplished within the multilayer motherboard.	Reference 1

PACKAGING CONCEPT: EVALUATION CRITERIA - CENTRAL COMPUTER (NADC) COMPLEX (CCC)
MODULE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
RFI-EMI Shielding Design	Not included in module design.	
Module Keying or Indexing Scheme	Matching color bands may be used at the top of the module and on the side rail of the housing in which it mounts. Each submodule connector has one over-size guide pin for positive polarization.	Reference 1
Module Complexity (Level of Electronic Function)	Each CCC module performs a complex digital function	
Module Repair Level	The four submodules making up a module are throw-away-at-failure	Reference 1
Module Reproducibility		

PACKAGING CONCEPT: EVALUATION CRITERIA - CENTRAL COMPUTER (NADC) COMPLEX (CCC)
ENCLOSURE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
General Description of Enclosure Design Features	The housing containing the CCC modules are rack and panel mounted in the aircraft by two shear/guide pins located at the unit rear. Each of the housings are specially dimensioned to contain a specific number of modules. These enclosures are not considered applicable as standards.	
Weight of Enclosure (Excluding Electronics Payload)	Not Applicable (N/A)	
Sizes of Enclosures and Chassis	N/A	
Chassis Design Features	N/A	
Heat Transfer Units and Features	N/A	
Interrack (Chassis) Cabling Features	N/A	
Interenclosure Cabling Features	N/A	
Volumetric Efficiency	N/A	
Gravimetric Efficiency	N/A	
RFI-EMI Shielding Design	N/A	
Mounting Provisions and Area Required	N/A	

PACKAGING CONCEPT: EVALUATION CRITERIA - CENTRAL COMPUTER (NADC) COMPLEX (CCC)
ENCLOSURE DESIGN

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Enclosure Components Producibility	N/A	
Displays and Controls Mounting Features	N/A	

PACKAGING CONCEPT: EVALUATION CRITERIA - CENTRAL COMPUTER (NADC) COMPLEX (CCC)
LIFE-CYCLE COSTS

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Prior Qualification to Military (Navy) Operational Environments	Design requirements: Shock - 60 g's for circuit/module Vibration - MIL-E-5400 (Curve IV, Figure 5) No shock mounts of any type are used, either in the housings or in the modules.	Reference 1
Use of Packaging Concept in Systems and Equipments	The CCC modules form a part of IHAS, to be used on the Navy's CH-46 and CH-53A helicopters.	
Design Documentation Status	Status not known.	
Sources of Packaging Concept Components	Single source on completed modules. Circuit chips are available from two sources.	Reference 1
Cost of Packaging System Components		
Availability of Packaging System Components		

PACKAGING CONCEPT: DESIGN CRITERIA - CENTRAL COMPUTER (NADC) COMPLEX (CCC) LIFE-CYCLE COSTS

TECHNICAL CHARACTERISTICS	COMMENTS	DATA SOURCE
Brief History of Concept Development	The CCC modules were designed specifically for a digital avionics system for use onboard helicopters.	Reference 1
Design Philosophy	The design of the CCC modules was guided by the requirements for an avionics system. Minimum weight, volume and maximum reliability were overriding design considerations.	
Design Applicability for Navy Electronic Systems	The CCC module design is applicable to installations requiring extreme volumetric and gravimetric efficiency	
Name of Developing Agency or Company	The CCC modules were developed at the Naval Air Development Center (NADC).	Reference 1
Group or Individual to Contact for Additional Information	Mr. J. Roach, Code AEHE U.S. Naval Air Development Center Johnsville, Pennsylvania	Reference 1

Table A-1
NELC Enclosure Weights

Weights of Type A Electronic Equipment Enclosure Assembly (excluding electronics, wiring, and cooling), Associated Parts and Securing Hardware:

	REFERENCE DWG. NO.	DESCRIPTION	WEIGHT (Lbs.)
*1	RAAF10463	Enclosure Assembly (Type A) with 2 Type I Serviceable-Main-Chassis and junction box	700
*2	RAAF10463	Enclosure Assembly (Type A) with 2 Type II Serviceable-Main-Chassis and junction box	738
*3	RAAF10463	Enclosure Assembly (Type A) with one Type I and one Type II Serviceable-Main-Chassis and junction box	719
4	RAAF10468	Cabinet Assembly (Type A) with top and bottom slides and junction box	470
5	RAAF10468	Cabinet Assembly (Type A) with top and bottom slides only	413
6	RAAF10506-1	Junction Box Assembly including attaching hardware	57
7	RAAF10468	Cabinet Assembly only (Type A)	257
8	RAAF10464	Type II Chassis Assembly with latch assembly and guide pins (RAAF75101)	134
9	RAAF10473	Type I Chassis Assembly with latch assembly and guide pins (RAAF75101)	115
10	RAAF10494 & RAAH10128 (plus mounting hardware)	Top and Bottom Slide Assemblies (for both Serviceable-Main-Chassis) including all mounting brackets, blocks and attaching hardware	156

Table A-1
(Continued)

	REFERENCE DWG. NO.	DESCRIPTION	WEIGHT (Lbs.)
11	RAAF10464	Type II Serviceable-Main-Chassis only	89
12	RAAF10473	Type I Serviceable-Main-Chassis only	70
13	RAAF10494	Top Slide Only	8
14	RAAH10128	Bottom Slide Only	61

* After installing RAAC75130 (RFI Gasket) and RAAC75131 (Cover) with associated water lines, valves, and fittings for cooling system (if required); these weights will increase approximately 15 pounds. Also, if cooling system is required, the weight of one cooling Module varies from approximately 70 to 90 pounds depending on the type of cooling required.

APPENDIX B
SHIPBOARD SPARES CALCULATIONS

Shipboard Initial Spares	
SHP Modules	Special Design
25 types of modules	40 types of modules
N = 40 modules/type/system	N = 12.5 modules/type/system
P ≈ .095 (probability of failure of one module in 5K hours with MTBF = 50,000 hours)	P ≈ .18 (probability of failure of one module in 5K hours with MTBF = 25,000 hours)
NP = 3.8	NP = 2.25
The spares demand is based on the binomial distribution.	
Assume .90 probability of having enough spares of all types	Assume .90 probability of having enough spares of all types
MOD = $\sqrt[25]{.90}$ = .9958	MOD = $\sqrt[40]{.90}$ = .9974
Required: 9 spares/module type	Required: 7 spares/module type
9 spares/type x 25 types x $100/module = $22,500/ship	7 spares/type x 40 types x $150/module = $42,000/ship
If 5 types in other use, add only 5 spares for those common modules (see Conditions in Chapter III)	
(20 x 9 + 5 x 5) x 100 = $20,500/ship.	

Spares Replenishment	
SHP Modules	Special Design
Expected Failures: $\frac{25 \times 40 \times 5,000}{50,000}$ = 100/ship/5,000 hours 100 x \$100/module = \$10,000/ship/5,000 hours	Expected Failures: $\frac{40 \times 1.25 \times 5,000}{25,000}$ = 100/ship/5,000 hours 100 x \$150/module = \$15,000/ship/5,000 hours